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Sustaining salmon on the Trinity River, California : a case study on conflicting water uses

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Sustaining salmon on the Trinity River, California:

A case study on conflicting water uses

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ABSTRACT

The objective of this case study is to demonstrate the major importance and complex interdisciplinary interrelations required to achieve environmental restoration and sustainability of fishery resources. It substantiates the need for holistic approaches to develop self-sustaining, healthy, riparian ecosystems. Restoring limited natural fresh water resources requires a mixture of traditional and non-traditional techniques which often originate across disciplines.

In the case of the Trinity River, over a century of political, legal and scientific decisions have been considered to optimize its value. Weighing the need for irrigation, power production, a natural sustainable habitat for fish, and honoring the survival of indigenous people whose sustenance is predicated on the freshwater source, exemplifies the complexities that face many naturally occurring watercourses. Alone, mechanical restoration solutions such as dredging and annual gravel deposition to create salmon breeding areas, have not proven viable. After including an economic analysis of non-commodity recourses along with the traditional scientific approach, increasing flow variability and in-river water volume has emerged as the most appropriate sustainable restoration model.

CHAPTER 1. GENERAL INTRODUCTION

Introduction

For time immemorial, California's Trinity River served as a natural source of freshwater and fish for the indigenous people living near its banks (USFWS 1979). For the past 40 years, however, the physically diverted Trinity River has also been used to irrigate agriculture in the vast, arid Central Valley and to generate electricity via hydropower. The water diversions leave insufficient water in the river to support endangered migratory fish species or to sustain commercial, recreational, and tribal fisheries (USFWS 1979). Because the demand for the Trinity River water is greater than the supply, disagreements occur over allocation of river flow. Inevitably, decisions made by government officials favor one stakeholder over another (Ward 2002). As a consequence, litigation is often used to seek judicial decisions that override regulatory agencies.

The Trinity River once supported one of the most abundant Chinook (i.e. King) salmon *Oncorhynchus tshawytscha* runs in the west (USFWS 1979). After the Trinity River Division (TRD) of the Central Valley Project (CVP) was completed in 1963, 90% of the Trinity River flow was physically diverted eastward through a series of tunnels and power plants, to the Sacramento River which ultimately supplied water to the Central Valley (Eighty-fifth United States Congress 1955). Post-TRD, the Trinity River's salmon populations declined to 12% of their pre-1963 historic numbers (USFWS 1999). In 2002, 33,000 fish, primarily Chinook salmon, along 43 miles of the Klamath River below the junction with the low-flow Trinity River, died from gill-rot disease (CDFG 2003). The probable causes for this large salmon kill were rooted in the consequences of the water diversions (May 2002). The two causes, in order of critical importance, were low flows to the natural path of the Trinity River and the increased river temperature (USFWS 1999). To avoid future catastrophic kills, a judicial Record of Decision (ROD), based on the Department of the Interior's (DOI) scientific studies, ordered increased flows into the Trinity River (DOI 2000). This decision met resistance from Central Valley irrigation and Northern California power entities that had become dependent on the TRD for their water and power (Knapp 2001).

The Hupa and Yurok Native American Tribes, who have lived on the Trinity River for over 10,000 years, still depend extensively on abundant populations of Chinook, Silver (*O. kisutch)* and steelhead (*O. mykiss)* salmon for their food source, commercial livelihood, and ceremonial uses (DOI 1993). The Treaty of Peace and Friendship signed between the United States and the Hupa Tribe in 1864 was ratified in 1876 by a Presidential Executive Order and signed by President Ulysses S. Grant (Grant 1876; Thorton 1942). The order guaranteed the Hoopa Valley Reservation, a 12 by 12 mile parcel bisected by the Trinity River, "for the sole use and benefit of the tribes of Indians herein named". Because the Department of the Interior (DOI) was charged with further oversight of the sovereign reservation and since the depleted salmon stocks that followed TRD implementation posed a significant threat to the tribes' existence, the DOI was obligated to ensure sustainable fishing resources (Lockyear et al. 2003). The indigenous Native

Americans teamed with the federal agencies and challenged the irrigation and power entities' legal dispute over the ROD's recommendation for reduced flows from the Trinity River to the Central Valley.

Currently, the TRD's primary responsibility is to supplement the Sacramento River water for agricultural use in the naturally dry Central Valley. The Central Valley has nearly two-thirds of the cropland and almost 75 percent of the irrigated land in the state of California (CFBF 2004). California agriculture and related industries directly account for seven percent of the gross state product (CFBF 2004) and agriculture accounts for 43 percent of California's applied water use (Stene 1994). Central Valley agriculture supports 30 percent of all jobs in the state of California (CFBF 2004). Obviously, decisions affecting Trinity River water must be weighed against the economic impacts agriculture has on California's fiscal solvency.

As early as 1924, the Federal Energy Commission (FERC) recognized the Trinity River for its hydroelectric power potential (Stene 1994). In 2001, the demand for power in the State of California increased by 4% but the wholesale prices increased by 266%; a by-product of legislated deregulation and fabricated manipulation of electrical energy supply by Enron (Ackman 2005; Fisher 2003). Power became a major contributor to the state's multi-billion dollar budget deficit. The TRD helped alleviate the power strain with its 140,000 kW (kilowatt) hydroelectric capacity, achieved through three power plants powered by a 1,500 foot elevation drop between the Trinity River and the Sacramento River (Stene 1994).

Decisions over Trinity River water allocations continue to be weighed against the demands for inexpensive, domestic, "clean" hydropower.

In 2002, Westlands Water District, which supplies water to 600,000 acres of farmland in the Central Valley, and the Northern California Power Agency (NCPA), a consortium of 24 municipalities and power districts that combine financial resources to obtain favorable prices from shared energy sources, successfully filed a suit to stop the implementation of the DOI's ROD (Brazil 2001). The ROD was based on the Final Environmental Impact Statement (FEIS) developed by the Trinity River Restoration Program (TRRP). It required an increase in the natural flow of the Trinity River from 10% to 47%, but this created a 300,000 acre-feet reduction in flow to the Central Valley (USFWS 1983; Bacher 2000).

The Hoopa Tribe, organized sport fishers, and environmental activists appealed the decision to reverse the ROD. In November 2004, the Ninth Circuit Court rejected the Westlands Water District (representing irrigation concerns) and the NCPA's (representing energy concerns) petition to rehear the ROD decision and gave direction to increase flow to the Trinity River (Goodwin 2004).

Although elected officials at regional, congressional, and executive levels have participated in decision making regarding California's grand scale water projects from the onset, local elected officials have only recently been responsible for both environmental and economic policy regarding the Trinity River's water usage. Local authority is granted through voting membership in financially invested organizations, such as the NCPA. When the NCPA asked municipal members for support in joining Westlands' lawsuits against the ROD, a series of decisions were required.

As users of the hydroelectricity produced by the Trinity River, local representatives were indirectly tasked with 1) adopting an environmentally sensitive solution to protect declining Trinity River migratory fish populations, 2) recreating environmental balance in the Trinity River basin, 3) honoring treaties with Native Americans who depend on the Trinity River for sustenance and, 4) providing a constant source of “clean”, inexpensive energy to constituents.

Several mechanical restoration practices, such as dredging, ripping, re-creating side channels, importing gravel and reducing upstream erosion have been employed to create a more hospitable environment for migratory fish species in the Trinity River. It now seems that the most promising solution to sustain and/or enhance salmon resources is to increase the volume and variability of flow back into the Trinity River’s natural path.

Thesis Organization

The second chapter of this thesis follows the format required for articles submitted to North American Journal of Fisheries Management. It demonstrates the major importance of, and complex interrelations among economic, legal, and social issues on efforts to achieve environmental restoration and sustainability of fishery resources (USFWS 1999, 2004).

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CHAPTER 2. ENVIRONMENTAL POLICIES OF FISH VS. FOOD AND POWER: A CASE STUDY OF THE CHINOOK SALMON DISPUTE ON THE TRINITY RIVER, CALIFORNIA

A paper to be submitted to the North American Journal of Fisheries Management

Hillary H. Freeman

Abstract

Although Trinity River water resource allocation has been studied and debated for over a century, only recently have local elected officials had to make environmental policy decisions that directly impact the fate of this critical natural watercourse. The complex issues defining the debate on Trinity River Chinook salmon *Oncorhynchus tshawytscha* fisheries restoration and sustainability versus hydropower and irrigation span multiple disciplines. Future policy makers, scientists, and students can use this condensed historical record of scientific analysis, legal decisions, and social implications when addressing future fishery resource allocation challenges.

The Trinity River's natural fate was changed in 1955, when Congress authorized the construction, operation, and maintenance of the Trinity River Division (TRD). The TRD diverted 90% of the river flow to California's Central Valley (Eighty-fourth United States Congress 1955). By 1963, the Trinity River was physically manipulated via a series of dams, reservoirs, power plants, pipelines and tunnels

that diverted flow to the Sacramento River and irrigation canals for agricultural use in California's Central Valley. The initial purposes of the project were to improve navigation and ensure flood control of the Sacramento and San Joaquin Rivers (Stene 1994). Currently, the primary goals of the TRD are to supply water for irrigation and domestic use, and to generate hydroelectric power. A drastic reduction in the lower Trinity River natural Chinook salmon population was an unintended consequence of the TRD implementation (USFWS 1980). Until Congress mandated that the Central Valley Project (CVP) include preservation of fish and wildlife, environmental considerations were not considered (Eighty-fourth United States Congress 1955). Federal trust responsibilities for tribal fishery resources were later added as a decision criterion (DOI 1993).

In the 1970's, California Department of Fish and Game (CDFG) officials concluded that the TRD's 109 mile salmon habitat diversion, created by dam construction, caused severe decline in fish stocks. The CDFG recommended increased annual flows to restore habitats for specific life stages (CDFG 1974).

Many legislative acts, environmental impact statements, decisions, and memorandums have been signed in an effort to restore the fisheries in the Trinity River basin to the level that existed prior to the construction of the TRD. None of the remedies employed prevented a massive (33,000) salmon and steelhead trout (*O.mykiss*) kill in 2002 (CDFG 2003). It has not been possible to avoid the effects of the TRD on species depletion and simultaneously provide for the increase in demand for inexpensive, domestic, "clean" hydropower, water for irrigation, and the fulfillment of treaty obligations.

This case study illustrates the continuing struggle to strike a balance between competing water resource needs when demands exceed capacity (Reisner and Bates 1990). There is a need for increased interdisciplinary participation to capture the non-traditional variables that impact the solutions.

Historical Background

In the mid-1800's, spring-run Chinook salmon, *Oncorhynchus tshawytscha* were considered the most abundant salmonid in the Klamath Basin. As an adjunct industry to gold mining along the Trinity and Klamath Rivers during the late 1800's, canneries began operating. The fish harvest peaked in 1912, with about 141,000 salmon harvested and canned. In 1915, the numbers of Chinook salmon harvested declined to 72,400 or about half of the peak of 1912. By the early 1900's, over-fishing had reduced the spring-run populations to such low levels, that fall run Chinook became the most abundant in the basin (Snyder 1931).

Drought in the Great Plains during the 1930's destroyed crops and dust storms drove thousands of people to California. Nearly 500 miles of flat, arid desert, now called the Central Valley, would become checkered with small family farms if water could be found for irrigation. Irrigation water would come from large scale public works projects, such as the Central Valley Project. The ideas espoused in the 1870's to divert “excess” Sacramento River water to tracts in the vast Central Valley were finally validated with the onset of this westward migration.

Although the CVP began as an enormous public project destined for the betterment of westward expansion, the Central Valley soon became a political and environmental hotbed in the midst of changing contemporary needs. The CVP encompasses 35 counties in an area about 500 miles long and 60 to 100 miles wide, making it the largest United States Bureau of Reclamation (BOR) project. The CVP contains some of the country's largest dams. Many California politicians avoid dealing with the CVP because whatever the decision, large numbers of constituents will be offended, therefore, not many California citizens are aware of the fresh water and fresh water fisheries crises.

In spite of the social, legal, environmental, and political controversy surrounding the Central Valley Project, it remains an impressive accomplishment. The Central Valley comprises one-sixth of the irrigated land in the United States (CFBF 2004). The Central Valley's annual farm production exceeds the total value of all the gold mined in California since 1848. The Central Valley Project ranks first among BOR projects in value of flood damage prevented between 1950 and 1991. During that time period the CVP prevented more than $5 billion dollars in flood damage.

To encourage small family run farms, and to ensure equity and conservative use of the water supply, the Newlands Act established a federal reclamation policy limiting the amount of federal water individual Central Valley land owners could obtain to the amount necessary to farm 160 acres (Fifty-seventh United States Congress 1902). This limit would be increased in 1982 (Ninety-seventh United States Congress 1982). Water rights legislation began back in 1872 when rights were acquired by taking and beneficially using water. While some of permissive pre-

1941 water rights agreements are still active today, newer perpetual water rights legislation requires compliance with the California Water Code (SWRCB 1999).

Competition between the State of California and the Federal Government for operation and control of proposed large-scale diversion projects continued for 61 years. The decision to physically divert part of the Trinity River's natural watercourse, using a series of dams, reservoirs, power plants and an 11 mile tunnel, was approved by Congress and President Dwight Eisenhower in 1955, nearly 100 years after the concept was first made public (Chappie et al. 1982). The TRD portion of the CVP, built by the federal government, was completely operational in 1964 (Stene 1994).

The Trinity River starts from runoff of melted snow on the slopes the Trinity Mountains (elevations higher than 9,000 ft.). It traverses through Humboldt and Trinity counties in the northwestern corner of the State of California, eventually becoming the Klamath River's largest tributary (McBain and Trush 1997). Trinity Dam, which forms Trinity Lake, is first dam in the TRD series. Lewiston Dam, the second dam in the series, is located above Lewiston, California, and creates Lewiston Lake. Most of the river downstream of the Lewiston Dam was diverted southeast to the Judge Francis Carr Powerhouse via an 11-mile pipeline (Clear Creek Tunnel) before spilling into Whiskeytown Lake. Whiskeytown Lake is impounded by Whiskeytown Dam, Spring Creek Debris Dam and Spring Creek power plant. The water in Whiskeytown Lake spills into Spring Creek Tunnel or flows down Clear Creek. From Spring Creek Tunnel, the waters of the Trinity River merge with the Sacramento River and together they are diverted to California's Central

Valley (Figure 1). The non-diverted natural path fork of the Trinity River flows 109 miles from Lewiston Dam westward and divides the entire length of the Hoopa Valley Native American Reservation before merging with the Klamath River (which passes through the Yurok Indian Reservation) for 43 miles, eventually emptying into the Pacific Ocean (DOI 1994).

From 1964 to 1974, up to 90% of the inflow from the Trinity River into Trinity Lake was diverted from the Trinity River Basin into the Sacramento River Basin. This diversion level eventually caused substantial declines in the river's downstream fish population, especially migratory salmon . The diverted flow nearly dewatered 109 miles of salmon and steelhead habitat in the Trinity River downstream of Lewiston Dam. A portion of habitat destruction fell squarely in the middle of the 12 by 12 mile Hoopa Valley Native American Reservation (Figure 2). According to the Presidential Executive Order, signed in 1876 by Ulysses Grant, the Hoopa's have the right to the "sole use and benefit" of the parcel (Grant 1876).

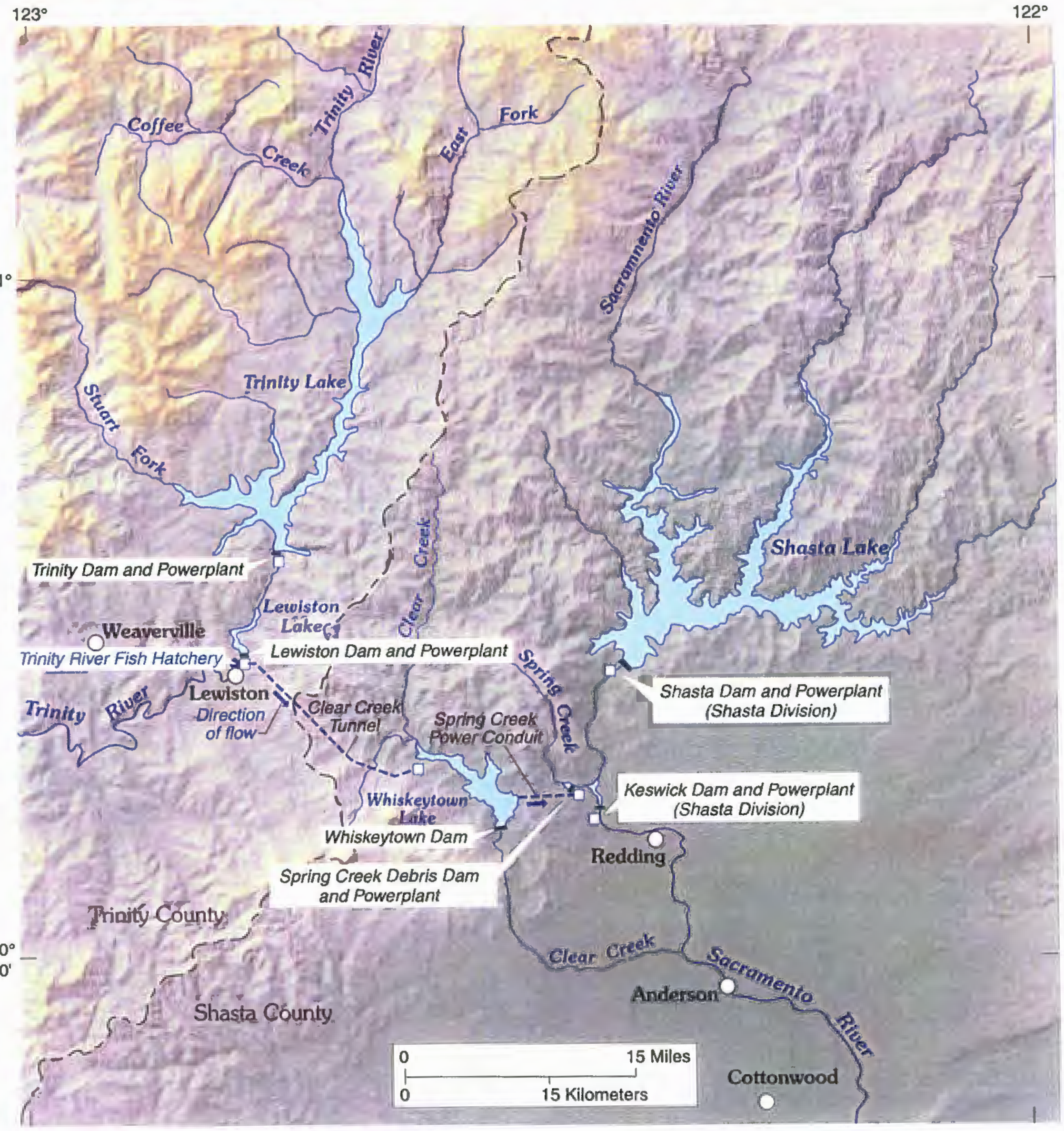

Figure 1. The Trinity River is diverted eastward near Lewiston Dam and Power plant via the 11 mile Clear Creek Tunnel , Whiskeytown Dam and Clear Creek before joining the Sacramento River, which flows into the Central Valley (USFWS 1999).

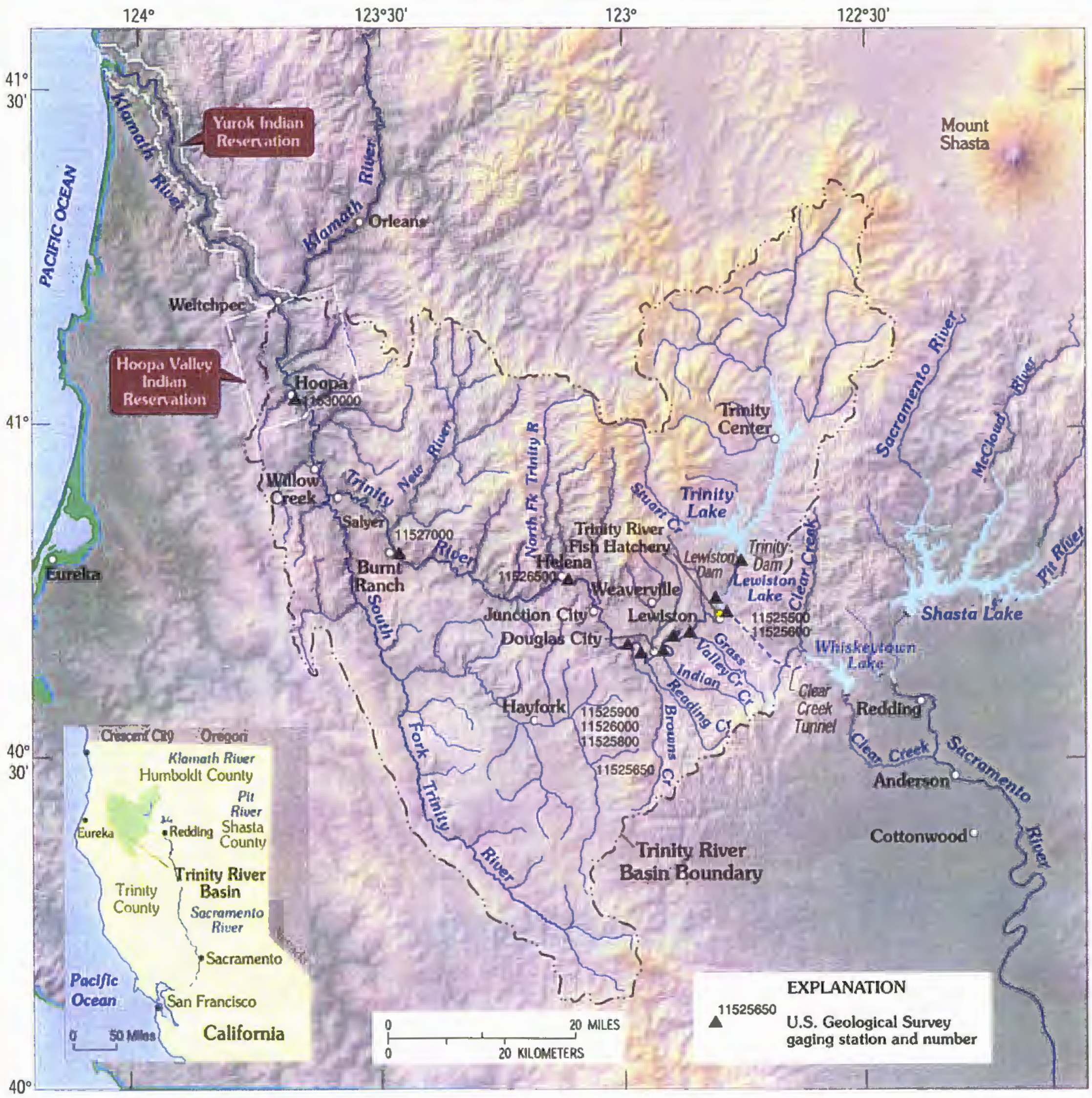

Figure 2. The Trinity River Basin highlighting the Hoopa Reservation where the Trinity and Klamath Rivers meet. The natural path flows west at Lewiston, through the Hoopa Valley Reservation, merges with the Klamath, passes through the Yurok Reservation and empties into the Pacific Ocean (USFWS 1999).

The declining fish stocks observed in 1971 (USFWS 2004) and the 1973 Endangered Species Act (EDA) compliance requirements encouraged the CDFG to perform a microhabitat study. The study concluded that the low rate of the annual stream flow to the natural Trinity tributary had to be increased to ensure restoration of specific migratory fish life stage habitats (Flosi et al. 1998).

In November 1980, an Environmental Impact Statement (EIS) concluded that the Chinook salmon population had declined by 80% and that an 80%-90% loss of salmonid habitat had occurred in the Trinity River's natural path since the completion of the TRD (USFWS 1980). The EIS cited three primary factors for the decline in fish population: 1) insufficient stream flow, 2) stream bed sedimentation, and 3) inadequate regulation of fish harvest. The Secretary of the Interior directed the implementation of measures "to restore natural fish and wildlife populations to levels approximating those which existed immediately prior to the construction of the Trinity Division" (Ninety-seventh United States Congress 1984).

The EIS analyzed habitat restoration projects, watershed rehabilitation, and improvements to the Trinity River Salmon and Steelhead Hatchery (TRSSH). It clarified that the hatchery's purpose was to compensate for the loss of the 109 miles of habitat downstream of Lewiston Dam. The restoration and rehabilitation projects were explicitly designed to increase natural fish production below the dam and to fulfill the federal government's trust responsibility to the Hoopa Valley and Yurok Tribes. A 1981 Secretarial Decision directed the United States Fish Wildlife Service (USFWS) to conduct the Trinity River Flow Evaluation (TRFE) Study in order to determine how to restore anadromous fish populations. The TRFE evaluated flow releases dependent on annual climate cycles, the effectiveness of mechanical watershed management projects, and recommended solutions that would rebuild the endangered Trinity River salmon and other migratory fish populations (USFWS 1999).

In 1982, presumably in response to the lobbying power of organized agribusiness which was beginning to dominate smaller 160 acre family farms in the Central Valley, the Reclamation Reform Act upgraded the acreage limit on the amount of federal water individual landowners could obtain from 160 to 960 acres. Even though two-thirds of California farms were less than 100 total acres, 80 percent of California farmland was comprised of farms larger than 1,000 acres. Seventy-five percent of California's agricultural production came from 10 percent of the farms. The Reclamation Reform Act also eliminated the residency requirement for farmers, increasing the likelihood of more large offsite agribusinesses (Ninety-seventh United States Congress 1982). More farming meant more irrigation requirements. The desert was made artificially fertile and wealth was created.

President George H. Bush signed the Central Valley Project Improvement Act of 1992 (CVPIA) as part of the Reclamation Projects Authorization and Adjustment Act (One hundred-second United States Congress 1992). The CVPIA greatly expanded environmental protection, restoration, and enhancement emphasis of the Bureau of Reclamation. The CVPIA reallocated 800,000 acre-feet of CVP water (600,000 in dry years) away from Central Valley farmers toward the restoration of stressed Trinity River fisheries. The CVPIA limited renewable agricultural water contracts to

25 years with no further long-term renewals. The CVPIA also created a $40 million-a-year restoration fund financed by water and power users.

For the Central Valley, the CVPIA created a stable, albeit smaller, reliable supply of quality water totaling up to 400,000 acre-feet for its wetlands. Supplemental water supplies were also deemed purchasable from willing sellers, in not less than 10 percent increments per year, with a maximum quantity of 163,259 acre-feet in 2002.

The CVPIA also directed the Secretary of the Interior to consult with the Hoopa Valley Tribe on the Trinity River Fisheries Environmental Statement (TRFES) and, with the tribe's agreement, to implement the restoration recommendations. Then California Governor Pete Wilson and legislators from the Central Valley were opposed to the CVPIA while environmentalists were supportive.

By 1996, congress re-authorized and amended the original Trinity River Basin Fish and Wildlife Management Act to clarify that “restoration is to be measured not only by returning adult anadromous fish spawners, but by the ability of dependent tribal, commercial, and sport fisheries to participate fully, through enhanced in-river and ocean harvest opportunities, in the benefits of restoration” (One hundred fifth United States Congress 1996).

At the turn of the 21st century, Central Valley agriculture conglomerates organized to oppose the legislative Record of Decision (ROD) upholding the Trinity River restoration plan (Brazil 2001). Representing billion dollar agriculture concerns, Westlands Water District gained immediate political influence by emphasizing the percentage (7%) of the gross state product generated from Central Valley farming and related industries (CFBF 2004). Westland’s focus was on the section of the ROD that mandated an increase in flow rates to the downstream Trinity River from water diverted for irrigation crops. California exports US$31.1 billion dollars in agricultural crops which is US$5 billion dollars more than Texas, Iowa, Nebraska, and Illinois combined. The Central Valley agricultural business also supports about 1.1 million jobs or 8% of the state's employment (CFBF 2004). These statistics bare weight with elected officials making policy decisions on Trinity River water allocations.

In addition to the TRD being a source of water for agribusiness, it is also a source of energy for many northern California jurisdictions. The energy crisis experienced by Californians in 2002 created demand for increased self-sufficiency from hydro power generated by dams and power plants, including those along the TRD. The TRD represents approximately 25 percent of the total power generation capability of the CVP, nearly 485,350 kilowatts (USFWS 2004). Any flow reduction through the power plants reduces energy availability. The trade off between higher energy costs and environmental restoration has entered the realm of local politics. Palo Alto and Alameda were the first member cities of the NCPA to send resolutions requesting that the agency stop joining Westlands in its legal actions aimed at blocking the restoration of the Trinity River, regardless of the slight impact (approximately U.S.$0.10/month) on local utility bills. Because Palo Alto is the third largest of 77 preference CVP power customers, with base power allocation equaling 12% of the 65% allocated to municipal utilities, locally made power policies have immediate economic impact and command receptivity (USFWS 2004).

In the 2002 Klamath River salmon kill, Chinook salmon contracted gill-rot disease while making their fall spawning run upstream in waters that were lower and warmer than their survival tolerance (CDFG 2003). The scientific answer to avoid future fish kills was to increase flows down the Trinity River's natural path (Zedonis 2003).

The resolution of Trinity River water conflicts reached new levels in July, 2004 when Judge Alfred T. Goodwin stated that 40 years of diversion of Trinity River water to the Sacramento River Basin had crippled the populations of migratory fish species. He ordered flow increases and more habitat rehabilitation projects (Goodwin 2004). The Westlands/NCPA appeal was rejected in November, 2004. In December 2004, the federal government paid agribusinesses US$16.7 million dollars for previously contracted irrigation water in order to increase the flows down the Trinity River (Boxall 2004). Notwithstanding the Goodwin ruling, powerful economic interests may continue legal retorts until the case is ultimately decided by the United States Supreme Court.

Environmental Impacts

Environmental concerns pertaining to the TRD implementation were initially addressed in section 2 of the 1955 Congressional Act which stated that the Secretary of the Interior will "adopt appropriate measures to insure the preservation and propagation of fish and wildlife" (Eighty-fourth United States Congress 1955). Congress specified that an average annual supply of 704,000 acre-feet, considered surplus to the present and future needs of the Trinity River, could be transported from the Trinity River to the Central Valley "without detrimental effect on the fishery resources" (Eighty-fourth United States Congress 1955). At the time, it was a commonplace viewpoint that discharging freshwater into the ocean, as was occurring from the Klamath River, was wasteful. Instead, the sustained diversion proved to have the severe effects on spawning salmon and natural recruitment. (USFWS 1999).

Over the first ten years of operation (1964-1973), the diversion allowed only 10% of the average annual flow of the Trinity River (140,000 of 1,396,000 acre-feet) below the Lewiston Dam (USFWS 1999). The flow rate ranged between 150 and 250 cubic feet per second (cfs) (TRBFWTF 1977). This flow regime and release schedule was expected to maintain or improve the Trinity River fishery resources and was based on the 1955 Act which estimated the need for 120,000 acre-feet (Eighty-fourth United States Congress 1955). The prescribed low flows did not have the power to maintain the oxygenated, clean, variably sized, gravel, spawning environment required by female Chinook for redd development (Evenson 2001; Matthews and Associates 2001a, 2001b).

Changes in average annual water temperature contributed to the Chinook habitat deterioration and increased favorability for the deadly parasitic nematode, *Nanophyetus salmonicola* (Foott et al. 1997). Pre-TRD water temperature patterns in the Trinity River's natural path (downstream of the Lewiston Dam) were colder in the winter months and warmer in the summer months than post-TRD water temperature patterns (Figure 3). Post-TRD average water temperature, throughout the year was at the lower end of the optimum range (50-62.6) for Chinook salmon juvenile rearing (Figure 3, Table 1).

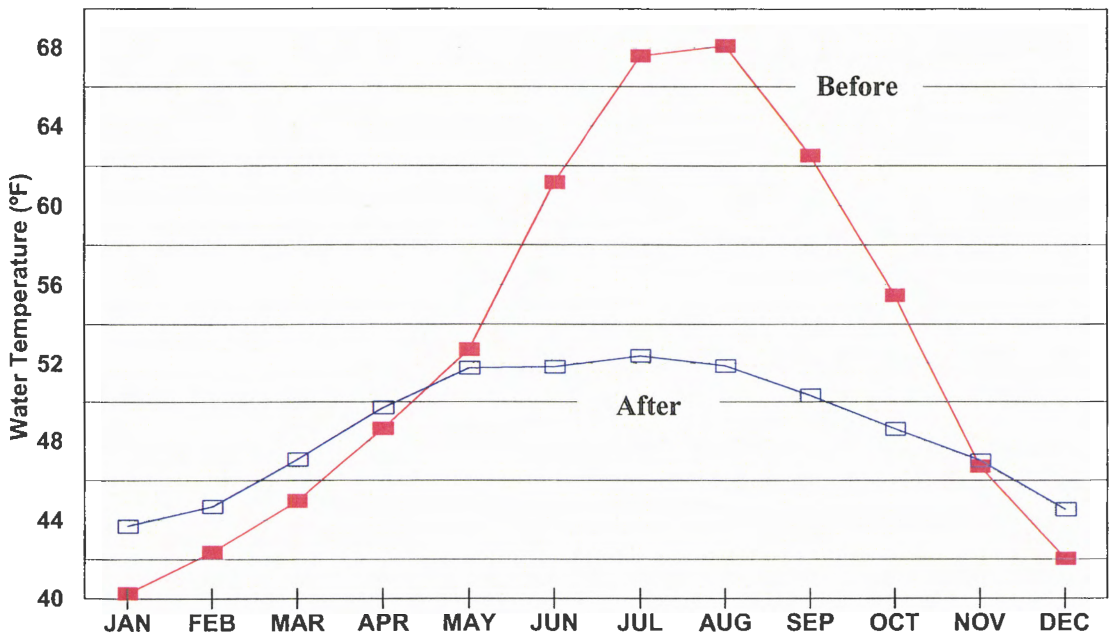

Figure 3. Mean monthly water temperatures of the Trinity River at Lewiston before and after the TRD in 1963. Data years were 1942 to 1946, 1959 to 1961, 1964 to 1983, and 1987 to 1992 (USFWS 1999).

Table 1. Water temperature requirements for Salmon (Zedonis and Newcomb 1997).Categories refer to the relative likelihood of ability to smolt (USFWS 1999).

Species	Category of Thermal Tolerance	Water Temperature (° F)	Source
	Optimal	50 - 62.6	Clarke 1992 , Clarke and Shelbourne 1985
Chinook Salmon	Marginal	62.6 - 68	Inferred between Clarke 1992 and Baker et al. 1995
	Unsuitable	>68	Baker et al. 1995

Optimal Chinook smolt temperatures range from 55 °F to 63°F in the spring and summer. These temperatures are sustained only when the flow reaches 4,000 to 6,000 cfs (Figure 3). For 44% of the juvenile rearing life cycle time frame, the average Trinity River water temperature is colder than optimal. According to the ROD, optimal dam release velocities in wet years are 4,000 to 6,000 cfs (Figure 4).

Optimal conditions create optimal year class populations (Table 2). If one of the environmental conditions is modified, year class smolt population may change. Increased smolt survival may increase the numbers of returning adults. Between 1982 and 1995 the number of Chinook in river spawners (excluding hatchery-produced spawners) ranged from 2,348 to 41,663 and averaged 11,044, or less than 25% of the average pre-dam estimate (47,600). Hatchery-origin fish commonly account for a large part of the fish spawning in river, but increases of naturally produced fish did not follow in subsequent years. More fish typically spawn in the river than return to the hatchery to spawn but fewer fish that were spawned in river as eggs survive to return as adults. This poor survival points to poor early life stage habitat conditions, assuming that hatchery produced fish suffer the same environmental conditions as “wild” Chinook from smolt to adult (USFWS 1999).

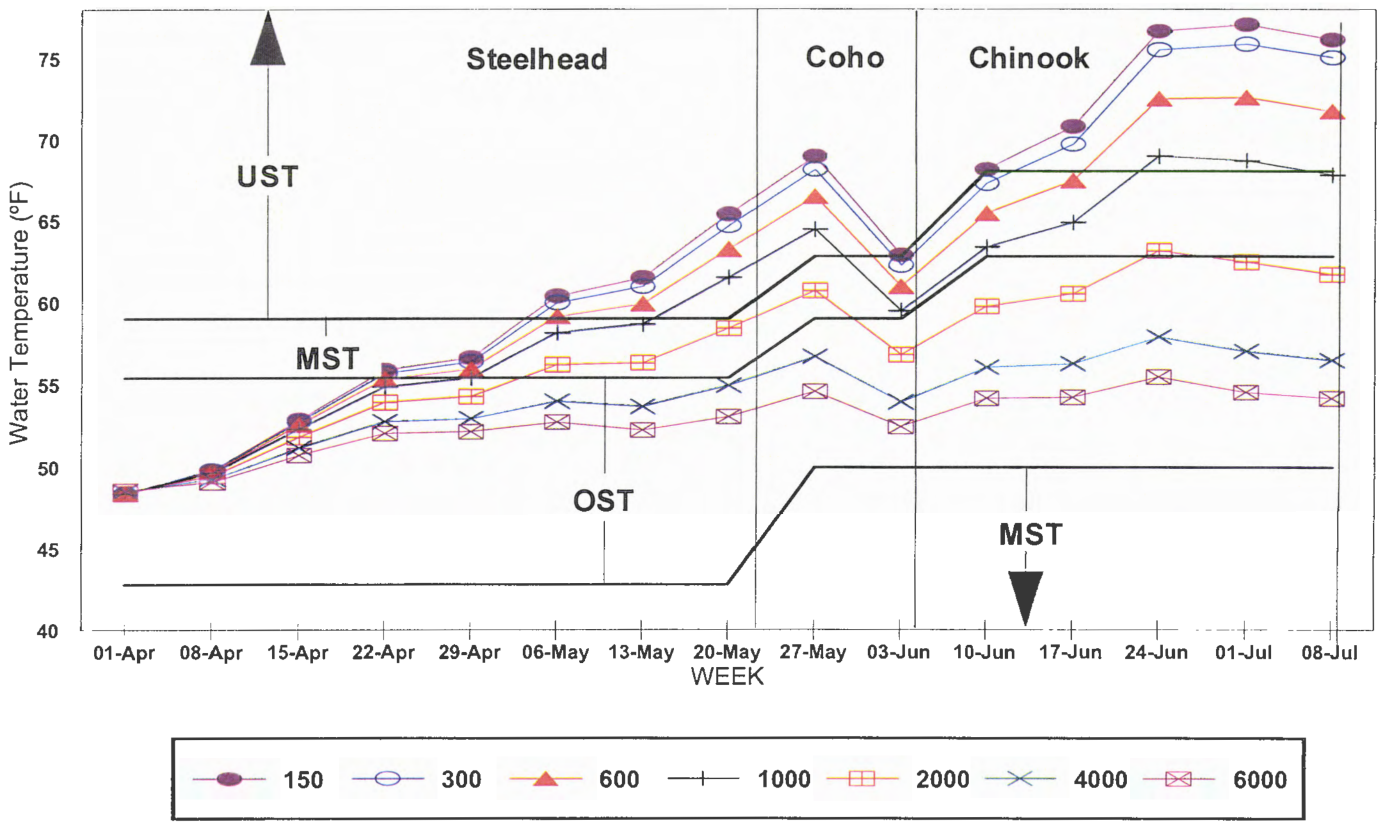

Figure 4. Water temperatures for the historic wet year (1984) with Lewiston Dam ranging from 150 to 6,000 cfs. Results are based on constant release temperatures. UST = unsuitable smolt temperatures, MST = marginal smolt temperatures, OST = optimal smolt temperatures (USFWS 1999).

Table 2. Chinook life history requirements (USFWS 1999).

Spawning requirements	Redd sizes	36 – 108 ft^2	Bjornn & Reisner 1991
	Territory sizes	144 – 216 ft^2	Burner 1951
	Gravel sizes	0.5 – 4.0 in.	Bjornn & Reisner 1991
	Velocities	0.33 – 6.2 ft/sec 0.1 -5.0 ft/sec	Healey 1991 Bjornn & Reisner 1991
	Depths	0.16 -23+ ft ≥0.78 ft	Healey 1991 Bjornn & Reisner 1991
	Eggs buried to depths	0.6 – 2.0 ft 0.65 – 1.4 ft	Healey 1991 Bjornn & Reisner 1991
Fry rearing requirements	Depths	shallow, stream margins	Chapman & Bjornn 1969 Everest & Chapman 1972
	Velocities	little to none	Chapman & Bjornn 1969 Everest & Chapman 1972
Juvenile rearing requirements	Depths	0.5 – 4.0 ft.	Bjornn & Reisner 1991
	Velocities	0 – 3.9 ft/sec	Everest & Chapman 1972 Bjornn & Reisner 1991
	Optimal rearing temperatures	44.6 – 57.2 ˚F	Rich 1987, Bell 1991
Smolt requirements	Optimal smolting temperatures	<59 ˚F	Clarke et al 1981, Pereira & Adelman 1985, Baker et al 1995

The average post-dam estimate (11,000) for naturally produced spawners was 8,000 less than the minimum pre-dam estimate (19,000) and the average post-dam estimate for naturally and hatchery produced spawners (35,230) was over 15,000 less than the average pre-dam estimate (47,600) (USFWS 1999). Empirically, there were significantly less salmon after dam implementation (Figure 5).
The Trinity River fall Chinook population hit a low in 1984 following 1983 El Niño conditions. El Niño conditions are caused by weak trade winds that allow warmer western Pacific waters to flow to the typically cool eastern Pacific, creating increased depths such that the upwelling of nutrients does not occur and food becomes scare (NAS 2005). The population returned from 1985-1989, partially due to regulated ocean fisheries. Fall Chinook dropped to all time lows in 1990-1993 before rebounding in 1994 and 1995 (USFWS 1999).

Between December and June, the Chinook's optimal period for egg incubation, fry emergence and especially for juvenile rearing and smolt migration, post-dam Trinity River flows have been, on average, significantly less than a pre-dam dry year (Figures 6, 7). This level of diversion, equivalent to a 10-year man-made drought, was reduced when post 1978 TRD dam released nearly 30% more water to the natural path of the Trinity River. The ROD recommended releases to coincide with water year volumes expressed in terms of dryness.

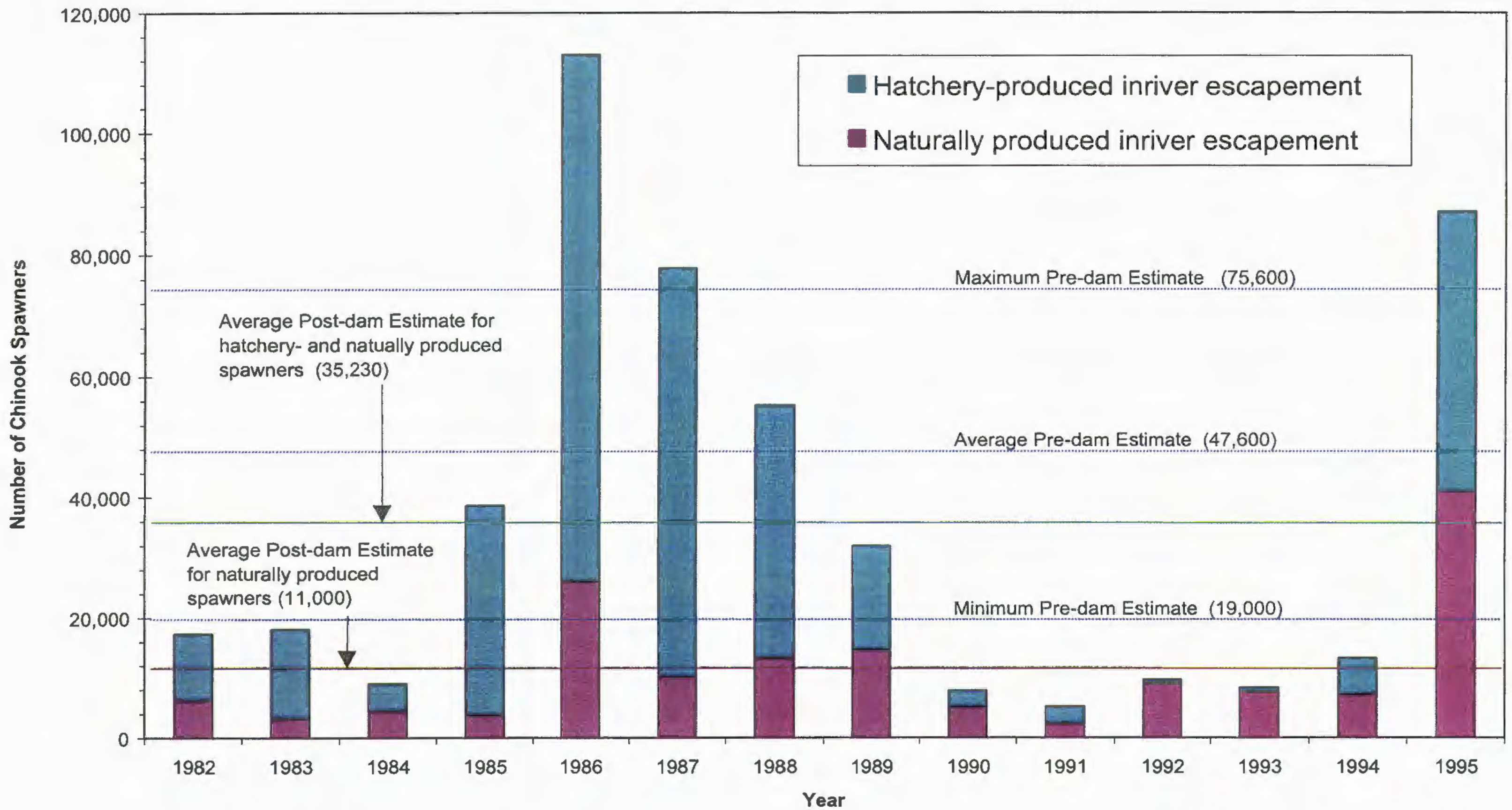

Figure 5. Post-TRD fall-run Chinook inriver spawner escapements (1992-1995) sorted by natural and hatchery produced spawners. Pre-dam estimates are based on data from 1944-1956 and 1963 (USFWS 1999).

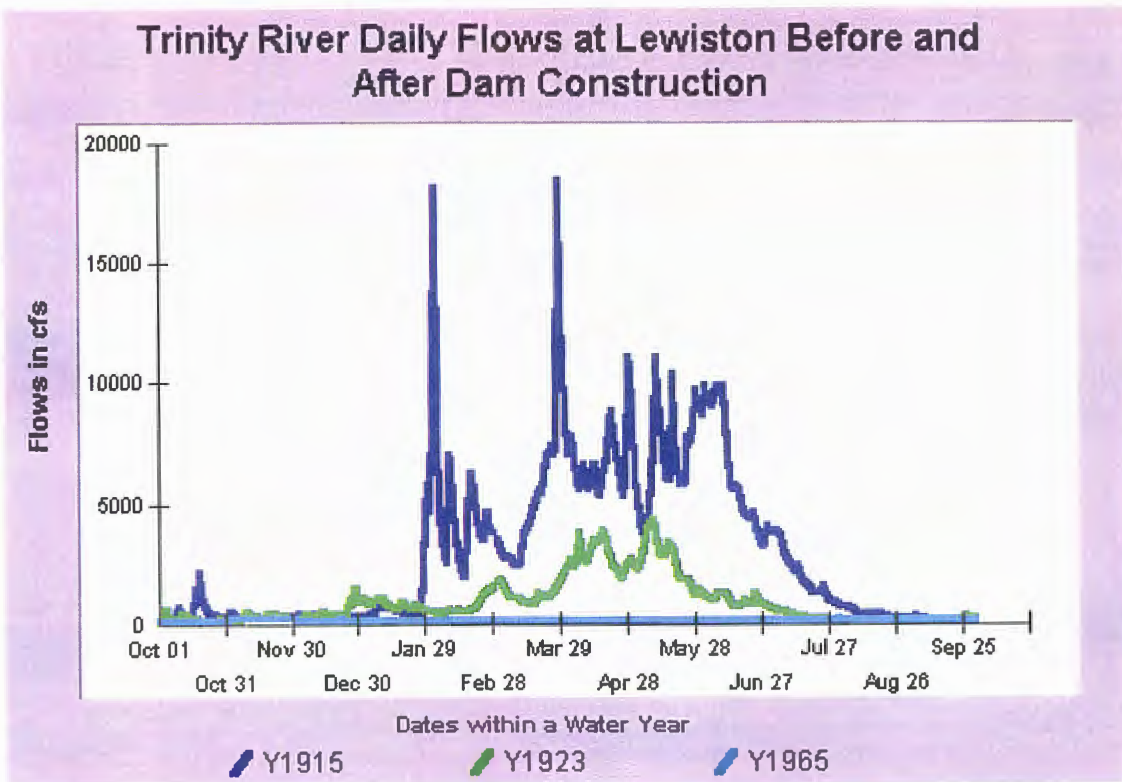

Figure 6. Trinity River flows before and after dam construction. The 1915 water year shows a typical pre-dam wet year with several substantial peaks in flow, including high flows into the early summer, from snowmelt. A pre-dam dry year (1923) shows small winter peaks but with substantial spring flow and variability. Post-dam Trinity River flows (1965) are very low and lack variability (USFWS 1999).

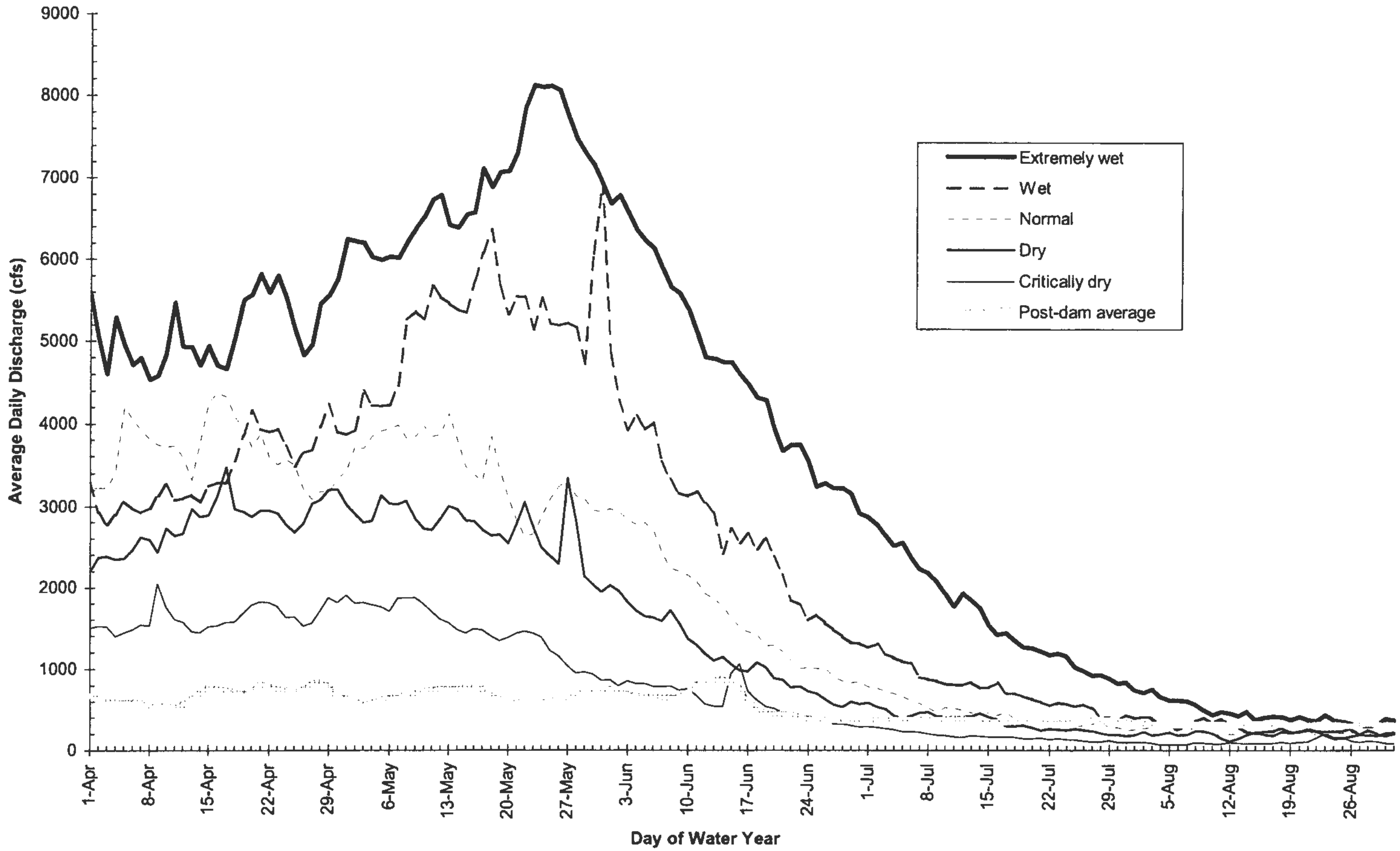

Figure 7. Average annual hydrographs of five water year classes and the post-dam average collected at Lewiston (USFWS 1999).

Restoration Efforts

Historically large water flows from the spring runoff naturally maintained a dynamic river channel that meandered and changed course over a wide alluvial plain. The straight portions of the river flowed swiftly, slowing at the river bends to create still, cool pools. The current truncated flow pattern has created a 40-year steady, slow flow scenario that opposes the pre-TRD variable flow patterns (Figure 8).

The post-TRD Trinity River conditions have not been favorable to salmon. Early restoration strategies included gravel replacement, gravel ripping, dredging, side channel creation, riparian growth containment, and feather edging. These mechanical solutions were designed to compensate for the excess sediment accumulation and reduced gravel availability in the river, in part due to the 90% decrease in flow. Many restoration projects have been designed to mimic what the river used to be like, with the intent of creating an environment more similar to that when the salmon thrived (Hampton 1988, 1997). All of the mechanical methods employed caused secondary environmental disruptions, primarily due to the use of heavy equipment in the fragile riparian environment.

Gravel necessary for building redds during spawning comes from the surrounding mountains. In the river, rock is tumbled smooth and pushed downstream, especially during high flows and flooding. Since the dams were built, the flow was reduced and the flow variability was eliminated (Figure 8). This low velocity flow stopped moving particles greater than sand and coarse sediment transport became negligible.

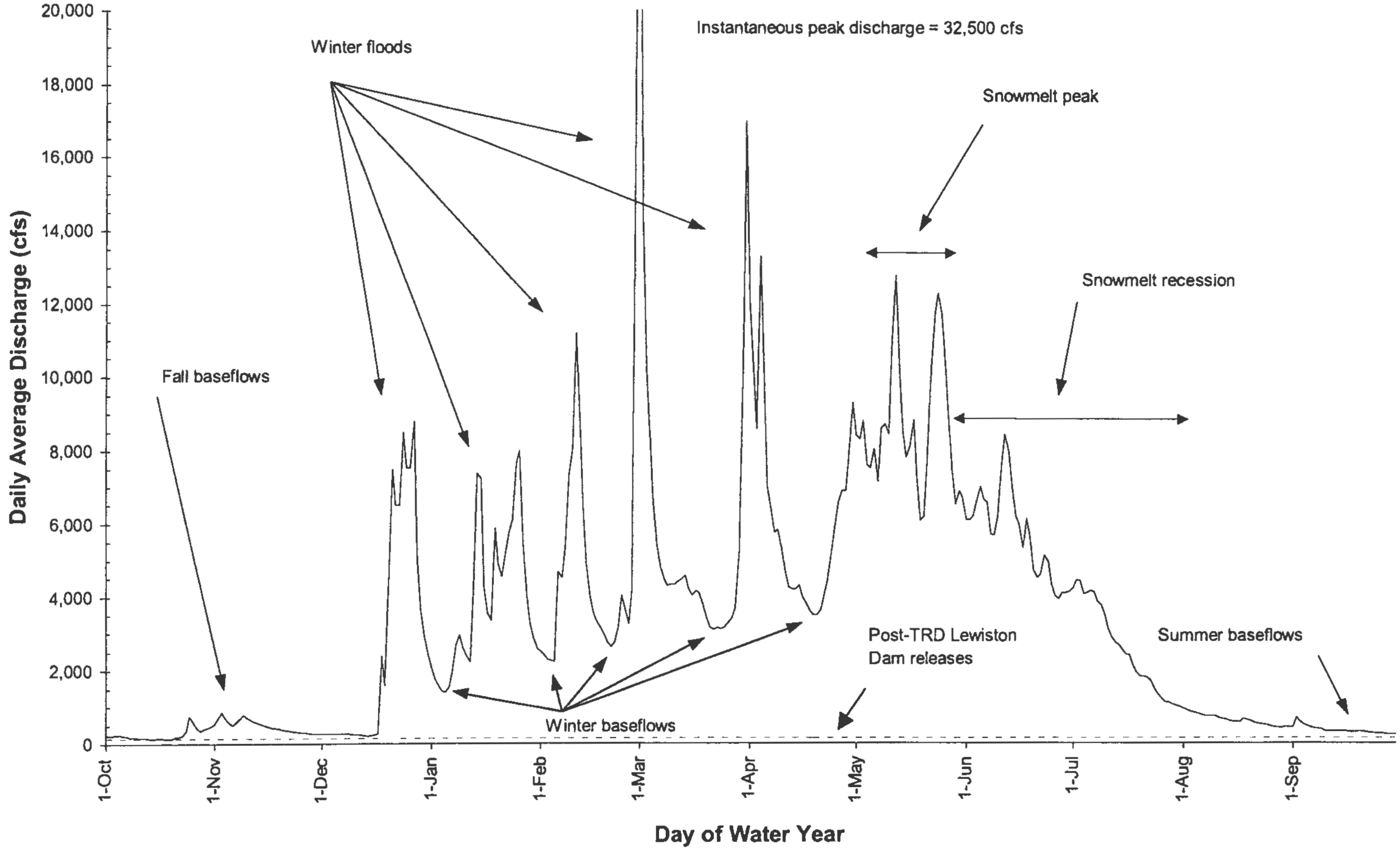

Figure 8. The Trinity River hydrograph is typical of a watershed dominated by rainfall and snowmelt runoff (Extremely Wet water to year 1941) compared the controlled post-TRD dam releases (USFWS 1999).

With the lower Trinity River physically blocked from receiving new gravel from the upper parts of the river basin, there were fewer places for salmon to spawn. To compensate for the annual gravel loss, gravel has been trucked into strategic locations along the lower Trinity River. Gravel replacement is still part of the Trinity River Restoration strategy (Matthews and Associates 2001a, 2001b).

The Trinity River Restoration Program (TRRP) has focused on erosion control and prevention to keep erodible soil on the hill slopes and out of the river. Instead of increasing flows to a level capable of moving eroded cement-like sands downstream, initial attempts to restore salmonid habitat included ripping the river bottom with heavy equipment to loosen the embedded gravel. Because adult spring Chinook especially need to rest in deep cold pools during spring and summer before spawning in September and early October, dredging was also used to remove sediment deposits from shallow sand filled pools that were once deep. The heavy equipment used for these mechanical solutions caused secondary siltation disturbances (Shelton and Pollock 1966). The current practice to decrease downstream sediment compaction is to stabilize the upland watershed (USFWS 1994).

Approximately 12 weeks after hatching, when the yolk is used up, the alevin leave the protection of the gravel as fry. Water temperatures during incubation are the primary environmental clues for embryo development rate and timing of fry emergence from the gravel (Alderice and Velsen 1978). The young fry, swim up to the surface to get air that is used to fill their swim bladders. At this stage, they are sensitive to the open stream habitat. Fry require low velocity shallow water frequently found in side channels. Because discharge was insufficient to create swift currents, the multi-channeled, wide Trinity River bed became U-shaped, with the water mainly confined to one channel. There are very few shallow margins to provide rearing habitats for juvenile Chinook salmon. Trinity River restoration includes recreating old re-growth side channels or creating new ones that mimic shallow, slower moving channels (Glase 1994). Mechanically creating side channels and feathering the edges creates slow back water areas where Chinook fry can hold and feed without swift currents (Gallagher 1995, 1999). Not all side channel rehabilitation has been successful, especially if the flow is not substantial enough for natural maintenance. Because of the mandated TRD flow reduction, the 1.5 year flood, largely responsible for channel formation, channel sizing, and moving coarse bed material, was reduced from 10,700 cfs to 1,070 cfs. Like dredging and ripping, side channel creation and maintenance is an environmentally disruptive solution. It has not been employed since 1995 (Flosi et al. 1998).

Riparian growth infringement (berms and bank side vegetation) due to low flow volume and velocities, is periodically mechanically removed (Pelzman 1973). This technique, called "feather edging", allows the water to spread out, creating shallow areas along the edges where flows are gentle enough for newly hatched Chinook alevin to grow in the oxygenated gravel and for swim-up fry to leave the gravel and start feeding (Gallagher 1995).

Other than the availability of gravel, the natural, variable flow release recommendation addresses most of the mechanical solutions tried in the past. Variable flows of sufficient size clean spawning gravels, build gravel bars, scour sand out of pools, oxygenate water, hold riparian encroachment at bay, provide adequate temperature and habitat conditions for fish and wildlife at different life stages, and perform many other ecological functions. Without strong flows to sustain them, mechanical solutions require continuous, expensive maintenance (BOR 2000). The December 2000 ROD, confirmed by the Ninth Circuit Federal Court in 2004, allowed increased flows which could possibly eliminate the need for most mechanical intervention (Goodwin 2004).

To recreate inter-annual, or "between-year" flow variability, the ROD defined five, water-year types with a minimum volume of water to be released into the Trinity River for each of the five types (DOI 2000). Each year, the water not allocated to the river is available for export to the Central Valley for water supply and power generation. Intra-annual, or "within-year" flow variability is incorporated into the hydrograph plan to meet specific restoration objectives.

With exception of bed material cementation, sub par post-TRD conditions identified as being reversible by increased flow allocation and variability have shown positive results (Table 4).

Table 4. Summary of actions taken or suggested to restore the mainstem Trinity River to pre-TRD conditions in order to restore anadromous fish populations (USFWS 1999).

Condition	Reversal Measure	Positive or negative Results	Slated for continuation
Low flow	Small increases	negative	yes
Flow variability	Increased flow to mimic wet and dry periods	positive	maybe; sustainable levels are in dispute
Siltation	Dredging	negative	de-emphasized
Siltation	Stabilize upland watersheds to prevent erosion	positive	yes
Bed material cementation	Ripping	negative	no
Lack of spawning gravel	Gravel replacement	positive (some ecological disruption)	yes
Lack of spawning gravel	Increase flow allocation	positive	maybe; sustainable levels are in dispute
Bed material cementation	Increase flow allocation	?	maybe; sustainable levels are in dispute
Riparian encroachment	Berm removal and feather edging	positive and negative	maybe
Riparian encroachment	Increase flow allocation	positive	maybe; sustainable levels are in dispute
Loss of side channels	Excavation & enhancement of habitat complexity	marginally successful	only some maintenance
Loss of side channels	Increase flow allocation	positive	maybe; sustainable levels are in dispute

Conflict and Resolution

The decades-long battle regarding Trinity River water allocation continues in 2005. The major disputants in the conflict are the 2,500 member Hupa Indian Tribe and Westlands Water District, the largest irrigation district in the United States.

The Hupa Tribe, along with sport and commercial fishers, fisheries managers and environmental activists, support ensuring the health of the Trinity River, one of California's few fresh water sources and home to endangered anadromous fish stocks. They view a healthy river as spiritual, life sustaining, and necessary for harmonious environmental balance. The economic component of their argument is negligible compared to their long-term view (USFWS 1979).

Since the Westlands Water District and the NCPA's focus are on big business agriculture and energy interests, they attach immediate economic ramifications to their goal of providing water for agriculture and power to Californians. Commercial interests do not agree with most of the scientific information presented regarding the river's behaviors because it lacks substantive analysis of economic consequences.

In 2000, the ROD recommended increased water flows to the Trinity River's natural path (DOI 2000). The recommendation was based on a new EIS/EIR prepared for the Trinity River Mainstream Fishery Restoration Program (TRMFRP) by multiple stakeholders: the Fish and Wildlife Service (FWS), United States Bureau of Reclamation, Trinity County, and the Hupa Valley Tribe (USFWS 1983). The ROD was signed by the Secretary of the Interior. Since the supporting EIS/EIR was not certified by Trinity County it was not considered a finalized legal document under

CEQA (California Environmental Quality Act) regulations. The Central Valley water and power interests immediately filed suit seeking to stop implementation of the ROD, partially based on the lack of Trinity County CEQA certification (McBain and Trush 2002).

In 2001, a federal court (Fresno, CA) issued a Memorandum Decision and Order stopping the federal defendants from implementing any of the flow related rulings made in the ROD (Wagner 2002). The court found that the mechanical alternatives in the two biological opinions and potential effect of decreasing an energy source during the California energy crisis were not adequately analyzed in the EIR/EIS. The federal agencies involved were directed to address these issues in a Supplemental Environmental Impact Statement (SEIS) and to begin soliciting public input and comment on this process, clarifying that the overall objective was to meet federal trust responsibilities to maintain and restore tribal fishery resources in the Trinity River to the level that existed prior to the construction of the TRD (USFWS et al. 2004).

In 2003, United States District Judge Oliver Wagner (Fresno, CA), ruled that federal water managers could release more water to the Trinity River to boost flows in the Klamath River in order to prevent a repeat of 2002's massive salmon kill. Federal biologists testified that the continued mandated drought in the Klamath Basin combined with another large return of salmon in the Klamath River and its tributaries could recreate the conditions that produced the 2002 kill. Judge Wagner gave the BOR permission to release up to 50,000 acre-feet of water beyond the maximum mandated annual flow. Although this ruling was more favorable than those in the past, the Hupa tribe appealed to try to restore flow rulings originated in the ROD.

In July of 2004, a three judge panel of the Ninth Circuit Court of Appeals (San Francisco, CA) ordered the permanent restoration of 47% of the Trinity River's pre-TRD flow and the habitat restoration initially ordered in the 2000 ROD (Goodwin 2004). The flow schedule was designed to prevent unnatural fish kills by mimicking natural flows. The order increased flows from 450 cfs to 1,650 cfs, and then gradually ramped back down to 450 cfs, within a three week time period. This flow schedule used the entire 368,000 acre-feet of Trinity water designated for critically dry years, and allowed, without further approval, up to 815,000 acre-feet in very wet years. This schema leaves an average of 52% (versus 75% - 90%) of Trinity River water flowing to the Central Valley (Table 3).

Table 3. Recommended annual water volumes for instream release to the Trinity River in thousand acre-feet (USFWS 1999).

Water-Year Class	Instream Volume
Extremely Wet	815.2
Wet	701.0
Normal	646.9
Dry	452.6
Critically Dry	368.6
Average (weighted water-year probability)	594.5

Judge Alfred T. Goodwin's writings on the ruling underscored that during the 40 years of TRD, migratory fish species "have been decimated by the decades of reduced water flows". He also stated that according to former Interior Secretary Bruce Babbitt's 2002 ROD, the restoration plan would equate to "a reduction in the statewide electrical energy supply of approximately one-tenth of one percent." Goodwin declared that "The number and length of the studies on the Trinity River, including the EIS, are staggering, and bear evidence of the years of thorough scrutiny given by the federal agencies to the question of how best to rehabilitate the Trinity River fishery without unduly compromising the interests of others who have claim on Trinity River water" (Goodwin 2004).

The battle over water is far from over. There is still room for further legislation. A petition by Westlands and the NCPA to the Ninth Circuit Court (San Francisco, CA) for a rehearing in front of the same three judges was rejected in November 2004. Westlands still has the legal option to petition for a United States Supreme Court review.

But progress between the two sides is occurring. Upholding the ROD's orders should improve conditions for salmon growth and migration (AP 2003).

Policy Makers, Implementers, and Stakeholders

Congress has given responsibility for the Trinity River Fish and Wildlife Management Program (Trinity Program) to the U. S. Secretary of the Interior who has assigned day-to-day responsibility for the Trinity Program to the U. S. Bureau of Reclamation, the CVP's operating agency.

The Trinity Program has a policy steering committee, named the Trinity Task Force, comprised of concerned state and federal agencies and Trinity River "stakeholders" - the timber, fishing, and Native American tribal communities. The Trinity Task Force is assisted by a Technical Coordinating Committee (TCC.) The TCC receives proposals for restoration projects from interested entities and selects those projects that will, in its opinion, contribute to the program's success.

The TCC annually updates a Three Year Action Plan and recommends project direction and funding to the Trinity Task Force for approval. Recent restoration projects have focused on erosion control to prevent increased stream sedimentation rather than mechanical modifications or increased numbers of hatcheries.

While Native Americans, environmental activists, and most recently, environmentally sensitive municipalities and utility districts have sought to retain more water in the north and to have treaties with the United States honored, farmers, irrigation districts, and utilities portray the river as a crucial part of California's water-delivery and power-generating system, and that reducing the flows southward violates federal promises. To date, protests from either side have been relegated to the courts or the press, and not displayed as civil unrest.

The NCPA and farm-belt irrigation districts weighed in on the issue, siding with Westlands, specifically with regard to energy availability and irrigation, respectfully.

The Hoopa Valley Tribal Fisheries Department is responsible for the monitoring and reporting of the fishery for the entire Trinity River Basin. Funding comes from the Bureau of Reclamation, Bureau of Indian Affairs(BIA), BIA Compact, and National Marine Fisheries Service (NMFS) for the various monitoring activities including fish tagging, weir operations, juvenile outmigrant trapping, screw trap monitoring, creel census, and net harvest monitoring. Much of the data gathered through these monitoring activities is used to estimate future anadromous populations in order to determine allocation between the ocean fishery, Tribal fisheries, and the sports fishery.

In response to growing concerns about future water supplies, governments and water planners around the world are exploring ways to sustainably manage fresh water and anadromous resources to ensure there will be water for future generations. Efforts to manage fresh water for human needs must be balanced with needs of freshwater species and ecosystems of which humans are a part. Healthy freshwater ecosystems provide valuable natural services -- such as water purification, plant and animal foods, flood control, recreation, nutrient cycling, and biodiversity maintenance -- that could be lost without appropriate water management.

Water allocation decisions have real dollar costs. The water diverted back to its original path to increase the flows in the Trinity River was purchased from irrigation districts in California's Central Valley. The cost to move more than half the Trinity's flows across a mountain range and down the Sacramento River has been approximately $2.2 million per year for the past several decades. USGS economists Douglas and Taylor have determined that the "social cost of putting more water down the Trinity River is the sum of the lost consumer power from hydropower production as well as the value of the lost irrigation water" (Douglas and Taylor 1999). Preservation benefits for Trinity River instream flows and fish runs are $803 million per annum for the scenario that returns the most water down the Trinity River, a value that greatly exceeds the social cost estimate (Douglas and Taylor 1999).

In December 2004, the George W. Bush administration announced that it has agreed to pay $16.7 million to a group of Central Valley farmers and irrigation districts whose water deliveries were cut to protect endangered fish (Boxall 2004). This decision exemplifies a shift in decades of California water politics by promoting minimum standards for a healthy river and expecting lowered demands of water thirsty consumers (Hundley 2001).

When the TRD conflict surfaced, the age-old conflict between conservation and exploitive uses of natural resources occurred. More quantitative information on the "softer" data, such as the value of government trusts and the extrapolation the life expectancy of topsoil in the Central Valley under current farming practices may have helped diffuse some of the TRD conflict. In the volumes written on the Trinity River management problem, only a single attempt was made to quantify the economic effects of the TRD (Douglas and Taylor 1999). The results proved that currently, preservation of environmental resources could be more fiscally responsible, especially by reducing the large payments made to farmers for water not diverted, otherwise known as farm subsidies.

Conclusion

The inclusion of all stakeholders in the process, except for neglecting the CEQA requirement to get the Trinity County signature on the EIS, continues to be exemplary. Input included federal, state and local agencies, users (sport fishers, commercial fishers and the adjacent tribal communities), affected water districts, power associations and agribusinesses. Pooled research and multiple recommending bodies demonstrate the value of shared perspectives. Stakeholder advisory boards could work on gaining consensus on the weight of each factor contributing to the equation that defines the Trinity River's health. Traditional biological information collected by resource managers can be enhanced by assigning value to interacting non-biological variables. This approach would require managers to determine if the price (in time and money) to construct holistic formulas would increase clarity of decisions and reduce some conflict between stakeholders.

All information should continue to be gathered with enough rigor to face intense public and legal scrutiny. Future solutions to change the course of nature should be drafted on the basis of options that work with the nature in addition to the prevailing business mindset. Decision making case studies should be used to challenge students to determine what information is necessary, from multiple competing perspectives, to make important environmental decisions and to use interdisciplinary teams to develop sustainable solutions. Early agreement on the process and information necessary to make decisions is crucial. The decision on the TRD took

30 years to finalize; much too long to prevent permanent environmental catastrophes.

The Trinity River environmental management scenario is ongoing. Many questions remain. Is there a way to find a balance between the fresh water needs of people and ecosystems using the Trinity River? Can water be stored and diverted in a manner that can sustain the ecological integrity of affected river ecosystems and address human needs? Can we institute environmental management methods that are sustainable? What is the cost of not protecting fresh water ecosystems? Trinity River policy makers' dilemma weighs the economics of food supply against the long-term effects the river diversion has on the ecology of a river. The next generation of environmental managers should continue to work to devise quantitative, interdisciplinary solutions that treat each soft (e.g. social capital) and hard (e.g. population dynamics) measure as weighted variables in a holistic formula that includes economic ramifications.

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